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Proceedings of the Joint Canada – USA Review Group on the Stock Assessment of Coastal Pacific Hake/Whiting Stock off the West Coast of North America February 20-22, 2002

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PACIFIC SCIENTIFIC ADVICE REVIEW COMMITTEE (PSARC)

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Summary

The second joint meeting of the Canadian Pacific Scientific Advice Review Committee (PSARC) Groundfish Subcommittee on Pacific Hake and the USA Pacific Fishery Management Council's Stock Assessment Review (STAR) Panel for Pacific Whiting was held at the NMFS Montlake Laboratory, Seattle, WA, USA February 20 – 22, 2002.

The Panel agreed with the Helser et al. (2002) assessment that the best estimate of 2001 stock abundance is 0.7 million mt, with uncertainty as indicated from the approximate probability density functions. The Panel noted that:

- Stock size has declined continuously over the past four years to its lowest point of 711 thousand mt in 2001.
- The exploitation rate increased from below 10% prior to 1993, to 31% in 2001.
- The mature female biomass in 2001 is estimated to be 20% of an unfished stock.
- Mature female biomass is projected to rise over the next three years as the above-average 1999 year-class enters the mature biomass of the stock.
- The percentage of unfished stock size and the future yield trajectory, depend heavily on the estimated strength of the 1999 year-class, persistence in the recent increases in weight-at-age, and harvest policy chosen.

The Panel concluded that the F45% policy along with the 40-10 rule is the most appropriate for this stock. A yield range for 2002 (namely 96,000 – 133,000 mt) would be bounded by the low and medium 1999 year-class recruitment assumptions.

Given the dependence of yield options beyond 2002 on continued recruitment of the 1999 year-class and recruitment from year-classes not actually observed, the Panel recommended against adopting 2003 projections until another assessment is conducted.

Sommaire

Le Sous-comité des poissons de fond (merlu du Pacifique) du Comité d'examen des évaluations scientifiques du Pacifique (CEESP) du Canada et le Stock Assessment Review (STAR) Panel for Pacific Whiting du Pacific Fishery Management Council des États-Unis ont tenu leur deuxième réunion conjointe du 20 au 22 février 2002 au NMFS Montlake Laboratory de Seattle, dans l'État de Washington.

Les participants ont approuvé l'évaluation d'*Helser et al.* (2002) selon laquelle la meilleure estimation de l'abondance du stock en 2001 s'établit à 0,7 million de tonnes métriques, avec un degré d'incertitude comme l'indique la densité de probabilité approximative. Ils ont aussi noté ce qui suit :

- Le stock a diminué constamment au cours des quatre dernières années, atteignant leur niveau le plus bas en 2001 (711 000 tonnes métriques).
- Le taux d'exploitation est passé de moins de 10 % avant 1993 à 31 % en 2001.
- Selon les estimations, la biomasse des femelles adultes en 2001 représente 20 % d'un stock non exploité.
- La biomasse des femelles adultes devrait augmenter au cours des trois prochaines années puisque la classe d'âge « supérieur à la moyenne » en 1999 tient compte de la biomasse des poissons adultes du stock.
- Le pourcentage du stock non exploité et la trajectoire du rendement futur dépendent largement de l'effectif estimé de la classe d'âge 1999, de la persistance des récentes augmentations du poids selon l'âge et de la politique de pêche choisie.

Les participants ont aussi conclu que la politique « F45% » et la règle « 40-10 » sont celles qui conviennent le mieux à ce stock. La gamme de rendement pour 2002 (soit de 96 000 à 133 000 tonnes métriques) serait fixée en fonction des hypothèses de recrutement selon la classe d'âge (inférieur et moyen) de 1999.

Étant donné que les options de rendement après 2002 sont tributaires du recrutement continu de la classe d'âge 1999 et que le recrutement à partir des classes d'âge n'est pas réellement observé, les participants ont recommandé de ne pas adopter les prévisions de 2003 avant la réalisation d'une autre évaluation.

Introduction

The second joint meeting of the Canadian Pacific Scientific Advice Review Committee (PSARC) Groundfish Subcommittee on Pacific Hake and the USA Pacific Fishery Management Council's Stock Assessment Review (STAR) Panel for Pacific Whiting was held at the NMFS Montlake Laboratory, Seattle, WA, USA February 20 – 22, 2002. The list of participants is given as Appendix 1.

The joint PSARC Subcommittee – PFMC STAR Panel (hereafter referred to as the Panel), received the primary draft assessment document prior to the meeting:

Helser, T.E., M. W. Dorn, M.W. Saunders, C.D. Wilson, M.A. Guttormsen, K. Cooke, and M.E. Wilkins. 2002. Status of Pacific hake/whiting stock in U.S. and Canadian waters in 2001.

Alan Sinclair (Canada) and Tom Jagielo (USA) served as co-chairs. Following a welcome by Dr. Elizabeth Clarke and introduction of attendees, the Panel heard the following presentations:

Overview of the Assessment	T. Helser (NMFS -- Seattle)
Results of the 2001 NMFS Acoustic Survey	M. Guttormsen (NMFS -- Seattle)

Results of the 2001 NMFS Shelf Survey	M. Wilkins (NMFS -- Seattle)
Results of the 2001 Canadian Acoustic Survey	M. Saunders (DFO – Nanaimo)

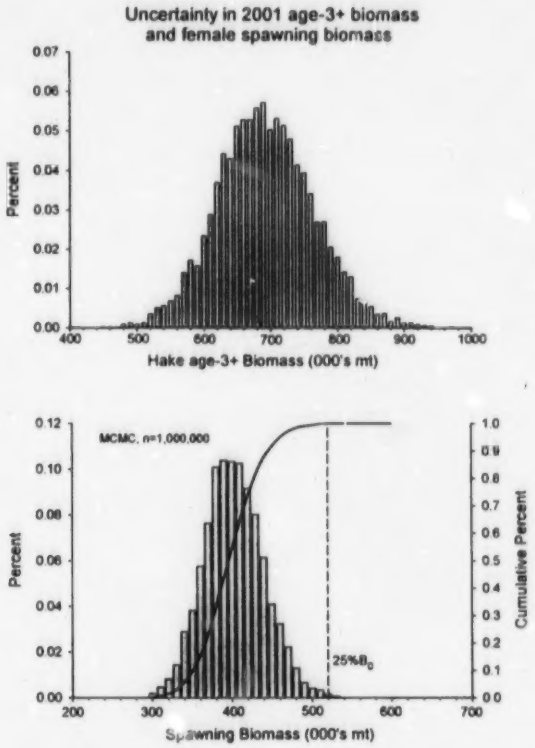
During their presentations and over the course of the 3-day review, the Stock Assessment Team (STAT) provided additional information and data at the request of the Panel that greatly assisted the Panel in carrying out its work.

A summary of the draft assessment document (prepared by the authors) is given as Appendix 2.

Summary of Stock Status

The Panel agreed with the Helser et al. (2002) assessment that the best estimate of 2001 stock abundance is 0.7 million mt, with uncertainty as indicated from the approximate probability density functions (Figure 26 of Helser et al., reproduced below). The Panel concurred with the assessment methods used in the analysis, and the approximate density functions for the stock projections.

- Stock size has declined continuously over the past four years to its lowest point of 711 thousand mt in 2001.
- The exploitation rate increased from below 10% prior to 1993, to 31% in 2001.
- The mature female biomass in 2001 is estimated to be 20% of an unfished stock.
- Mature female biomass is projected to rise over the next three years as the above-average 1999 year-class enters the mature biomass of the stock.
- The percentage of unfished stock size and the future yield trajectory, depend heavily on the estimated strength of the 1999 year-class, persistence in the recent increases in weight-at-age, and harvest policy chosen.



Detailed Comments from the Review

Surveys

It was generally agreed that the current approach of relying primarily on the results from the NMFS acoustic survey was appropriate for abundance estimation. The NMFS bottom trawl survey and the DFO acoustic survey do not cover the full geographical range of Pacific hake, and abundance trends derived from them may be biased due to changes in local availability. The last four NMFS acoustic surveys (1992, 1995, 1998 and 2001) have been the most reliable, in the sense that these surveys have unambiguously covered the entire area of the mature whiting distribution, including areas to the north and offshore that were not covered in previous years.

There were dramatic changes in the abundance and distribution of biomass between 1998 and 2001. The population biomass declined approximately 38% from the 1998 survey. In 2001 the majority of the biomass was present south of Newport, Oregon and in very low amounts off Washington and Canada, in contrast to 1998 when hake were present into the Gulf of Alaska with half of the biomass in the Canadian zone.

The Panel noted the strong selectivity at age evident in the model results for the NMFS acoustic surveys. Note that the selectivity function actually represents the confounded effects of acoustic selectivity, survey trawl net selectivity, and stock availability. The dome-shaped curve permitted by the double-logistic parameterization of selectivity resulted in lower apparent selectivity for younger and older age groups. A Bayes prior was imposed on the slope parameter of the ascending limb of the acoustic selectivity to achieve sensible results. Without the prior, peak selectivity shifts to older ages and results in an unreasonably large biomass of "unseen" young fish. The Panel recommended that possible explanatory factors for the dome-shaped selectivity be further explored prior to the next assessment, and that simpler parameterizations without a descending limb be considered, specifically:

1. Is the more complicated double-logistic selectivity formulation supported by the data;
2. Are there independent data to support the existence of older fish implied by a descending selectivity curve that are not available to the acoustic survey.

The STAT team presented an analysis of biomass distributions in the acoustic and Alaska Fisheries Science Centre (AFSC) bottom trawl surveys to address the issue of why the bottom trawl survey should be de-emphasized. The analysis indicated that hake biomass had shifted to shallower waters between 1995 and 2001. This suggests that the bottom trawl survey would be sensitive to changes in hake distribution rather than actual changes in stock abundance. Thus, the Panel agreed that the bottom trawl survey should retain low emphasis in the assessment model.

An index of juvenile hake abundance derived from the Southwest Fishery Science Center (SWFSC) mid-water trawl juvenile recruit survey (Tiburon survey) was used in the catch forecast but not in the stock reconstruction. A plot of the index vs. hake recruitment estimates from the stock reconstruction indicated a significant correlation, although it was relatively weak ($R^2 = 0.55$, $p = 0.002$). Over the 1986 to 2001 time-series of the Tiburon index, the 1999 year class is ranked 4th highest in the Tiburon time series but is the largest year class in the stock reconstruction. The Panel requested that a model run be completed where the Tiburon index is given the same weight at the acoustic survey. This run was requested since the Tiburon index represents a perspective on recruitment independent of the population dynamics model and thereby provides a second estimate of the size of the 1999 year-class. The runs emphasizing the Tiburon survey reduced the estimate of the size of the 1999 year-class by approximately 50%. However, the increased emphasis degraded the fit of the model to the age compositions from the acoustic survey and the fishery. The Panel recommended that the Tiburon survey index be incorporated into the base-line reconstruction runs using a CV of 0.5; 5 times that of the acoustic survey. This was considered reasonable given the apparent correlation between the index and the stock reconstruction and the use of the index in stock forecasts.

Biological Assumptions

The panel noted that weight and size-at-age has been variable over time. Declines during the 1980s were followed by an increase in 2000. The current weight-at-age vector is comparable to that seen in the mid-1970s. These changes are potentially linked to the following:

- changes in secondary productivity resulting in enhanced growth.

- environmentally induced shifts in distribution.
- ageing error.

Weight at age of Pacific hake tends to increase with latitude. For example, fish of a given age in the Canadian zone tend to be heavier than those distributed south of the zone. Thus, increased weight-at-age observed in the US zone in 2000 and 2001 could result from a southward shift in the distribution of hake, as well as from improved environmental conditions for growth.

The panel noted that the weight-at-age values used in the forward projections will have considerable influence on the resulting yields. It may be more appropriate to use a more conservative long-term mean rather than the mean of the last three years (1999, 2000, and 2001observations). The forecast increase in biomass depends in part on increased weight-at-age, thus, if the weight-at-age values are biased high over the term of the projections increased numbers of fish will be harvested to achieve the quota assigned in terms of weight.

The panel noted several issues related to the reproductive potential of the stock: First, the previous panel reported that the effect of a biomass consisting of a larger number of smaller individuals on true spawning potential is not well understood. They pointed out that spawning biomass appeared to have become progressively more heavily dependent on the contribution of 3, 4, and 5 year old females. The growing dependence on a few younger age classes has increased in 2002 with the population dependent on one year class of age 3's. Second, an important assumption in the current model runs is that the maturity ogive is time invariant. This ogive is based on a rather limited number of samples taken during the early 1990's. Given the current dependence on younger fish, the assumption of a constant maturity ogive needs to be examined in the next assessment.

Fisheries Data

The basic fisheries data for Pacific whiting appear to be sound, however the panel recommends that the next assessment include a more detailed description of the catch monitoring and sampling regime for each fishery. Future assessments should also include distributional plots for all fisheries and consider reporting a measure of fishing effort.

Model Evaluation

The draft assessment document distributed prior to the meeting presented three stock assessment models: Model 1, with status quo assumptions used to provide management advice since 1993, where acoustic biomass CV=0.5 in 1977-1989 and CV=0.1 in 1992-2001 (the AFSC trawl survey was de-emphasized for the entire time series (CV=100); Model 2, which treated the acoustic survey the same as Model 1 but increased the influence of the AFSC trawl survey (CV=0.1); and Model 3, which applied equal weight (CV=0.1) to the entire acoustic time series (1977-2001).

At the beginning of the meeting, the STAT team distributed summary results for two additional models: Model 4, which relaxed the assumption of acoustic survey catchability (q=1) by

estimating q for the entire time series (q=0.53); and, Model 5, which explored alternative acoustic survey selectivity for young fish by applying a penalty on ascending limb inflection and slope selectivity parameters.

The Panel expressed concern regarding the poor fit to the acoustic survey biomass under Model 1, and requested the STAT team conduct additional model runs to consider alternative assumptions of the acoustic survey selectivity at age and q. Recognizing that selectivity and q are confounded, and that the available data are not sufficient to obtain year specific estimates, the Panel requested the STAT team consider alternative models which treated the acoustic survey biomass time series as two separate indices of abundance; a pre-1992 time stanza, and a post-1992 time stanza. The rationale for the break in 1992 is drawn from uncertainty in the acoustic survey time series and environmentally driven changes in hake distribution.

The pre-1992 stanza is characterized by:

1. use of a single beam acoustic system (Biosonics 101);
2. required adjustments for northern and offshore expansion;
3. required adjustment for target strength;
4. Juvenile 0-2 age hake were primarily found in south-central California where plankton make acoustic assessment less effective;
5. The sphere calibrations at the start and end of the 1986 survey differed by 48% and the reconstruction uses the more conservative number.

The post 1992 stanza is characterized by:

1. Use of a new EK500 split beam acoustic system;
2. Adequate coverage of northern and offshore distribution;
3. Uses an appropriate target strength model adjusted for length;
4. Increased occurrence of Juvenile 0-2 age throughout the zone in most years.

Explorations of the two-stanza model structure included varying the treatment of acoustic survey selectivity (domed vs asymptotic) and q (fixed at q=1 vs. estimated) in the second time stanza. It appeared that this approach could improve the overall fit to the acoustic biomass time series, and some scenarios suggested increased catchability in the recent stanza. The panel attempted to evaluate the properties of the two-stanza models in more detail by: 1) performing a catch curve analysis on the acoustic survey and US fishery catch at age data; and 2) examining reasons for the degradation in the fit to the age composition data under some of the two-stanza scenarios. The Panel noted that the 1992 survey had substantially lower than expected numbers of age 2 and age 5 fish which contributed to lack of fit to age compositions and estimates of selectivity. However, the magnitude of the estimated increase in catchability was not supported by catch curve analysis of the survey data. Catch curve analysis of the US fishery catch at age suggested that the change in fit to the two stanza model may be influenced by changes in the commercial fishery data. Plots showed some indication of ageing error in 2001 and future assessments should consider incorporating year specific ageing error. In the time available, the Panel was unable to satisfactorily evaluate the full suite of two-stanza models presented, however, the Panel recommended that the two-stanza approach should be investigated further in the next assessment.

For the present assessment, the Panel agreed that Model 1 (with the SWFSC recruit index set at CV=0.5) should be used as the preferred assessment model. This model de-emphasized the earlier portion of the survey time series and provides a better fit to the more recent data. However, because the earlier part of the time series is de-emphasized, the fit to the entire acoustic time series is poor and a two stanza approach should be examined in the next assessment.

In contrast to the Panel consensus, the PFMC Groundfish Advisory Panel (GAP) member, who served as an advisor to the Panel at the meeting, did not concur with the sole use of Model 1, and suggested that Model 1 and Model 4 be forwarded to define the range within which management decisions should be made. He indicated that he would present his reasons in a separate statement to the PFMC.

Harvest Projections

Recruitment for the harvest projections was determined as a function of: 1) the mean log recruitment from the base-run model; 2) the SWFSC index of age-0 abundance; and 3) estimates of variability for the recruitment time series and the SWFSC recruitment index. The Panel did not discuss at length the merits of the SWFSC midwater trawl juvenile survey as a predictor of coastwide whiting recruitment, other than noting the limited geographic range of the juvenile survey and the typically high sampling error associated with juvenile surveys in general. The Panel recognized the high variance associated with forecasting recruitment and noted that caution in the use of the projections for forecasting future biomass levels may be prudent.

Stock Status

The Panel agreed with the assessment that the best estimate of 2001 stock abundance is 0.7 million mt, with uncertainty as indicated from the approximate probability density function (Figure 26 of Helser et al.). The Panel concurred with the assessment methods used in the analysis, and the stock projections shown in the projection table of the Summary of Stock Status (Appendix 2).

Harvest Recommendations

The Panel recommended exercising considerable caution in setting harvest levels for 2002. The caution is warranted given the following:

- The population biomass estimates have been declining continuously since 1987 and are at the lowest level observed;
- The 2002 stock is composed predominantly (63% by weight) of the 1999 year-class which is 3 years old and only 66% mature;

- Exploitation rates in the last three years were in excess of the 40-10 policy and the highest on record. The higher than projected harvest rates were primarily due to overestimation of stock size in the 1998 assessment and the fact that the combined Canada-US coastwide TAC's were set above the management target.

The Panel notes that the projected increase in yields between 2002 and 2004 is due to the estimated size of the 1999 year-class, the associated increase in stock size, and the increase in harvest rate due to the 40-10 rule. However, given concerns with the current formulation of the stock reconstruction model and the dependence of yield options beyond 2002 on continued recruitment of the 1999 year-class and recruitment from year-classes not actually observed, the Panel recommends against adopting 2003 projections until another assessment is conducted.

Management Goals and Objectives

Included in Appendix 2 is a projection table which provides: 1) coastwide yield; 2) 3+ biomass; and 3) percent unfished biomass under three arbitrarily assumed levels of recruitment in 2001 (derived from Low<10%, medium=10-90%, and High>90%; percentiles based on 1,000,000 Markov chain Monte Carlo simulations). For each assumed level of recruitment, projections are given under three harvest policies using the 40-10 rule (F40%, F45%, and F50%). Additionally, a decision table analysis is presented (Appendix 3) which shows the projected consequence of each management action under three states of nature, as if the assumed Low, Medium, or High recruitment levels are actually realized.

The Panel concluded that the F45% policy along with the 40-10 rule is the most appropriate for this stock. A yield range for 2002 (namely 96,000 – 133,000 mt) would be bounded by the low and medium 1999 year-class recruitment assumptions.

Summary of Panel Recommendations for Future Work (Not Prioritized)

- The next assessment should include a detailed description of the catch monitoring and sampling regime for each fishery.
- Possible explanatory factors for the dome-shaped selectivity curve should be further explored prior to the next assessment.
- The assumption of a constant maturity ogive should be examined in the next assessment.
- Reasons for the poor model fit to the acoustic survey biomass estimates of abundance should be further explored and model runs employing the two time-stanza approach should be investigated further in the next assessment.
- Given concerns with the current formulation of the stock reconstruction model and the dependence of yield options beyond 2002 on continued recruitment of the 1999 year-

class and recruitment from year-classes not actually observed, the Panel recommends against adopting 2003 projections until another assessment is conducted.

Appendix 1. List of Participants February 20-22, 2002

Name	Affiliation	20	21	22	Role
Richard Methot	NMFS/NWFSC	X	X	X	Observer
Mike Guttormsen	NMFS/AFSC	X	X		Author
Tom Helser	NMFS/NWFSC	X	X	X	Primary author
Chris Wilson	NMFS/AFSC	X			Author
Elizabeth Clarke	NMFS/AFSC	X	X	X	Observer
Kevin Piner	NMFS/NWFSC/GMT	X	X	X	STAR advisor
Sandy McFarlane	DFO/Pacific Biological Station	X	X	X	PSARC member
Tom Jagielo	WDFW/SSC	X	X	X	Co-chair STAR member
Alan Sinclair	DFO/Pacific Biological Station	X	X	X	Co-chair PSARC/STAR member
Norm Hall	CIE/Murdoch Univ. Perth	X	X	X	STAR member
Jeff Fargo	DFO/Pacific Biological Station	X	X	X	PSARC member
Rob Kronlund	DFO/Pacific Biological Station	X	X	X	PSARC member/STAR member
Mark Wilkins	NMFS/AFSC	X	X		Author
Rod Moore	Groundfish Advisory Panel	X	X	X	STAR advisor
Mark Saunders	DFO/Pacific Biological Station	X	X	X	PSARC member/Rapporteur
Ian Stewart	NMFS/University of Wash.	X		X	Observer
Vera Agostini	SAFS/University of Wash.	X	X		Observer
Ken Stump	Consultant- Environment	X	X		Observer
Rick Dunn	Hake Consortium of B.C.	X	X		Observer
Athol Laing	Hake Consortium of B.C.	X	X		Observer
Joe Bersch	Supreme Alaska Seafoods	X	X		Observer
Steve Joner	Makah Tribe	X			Observer
Jan Jacobs	American Seafoods	X	X		Observer
Guy Fleischer	NMFS/NWFSC	X	X	X	Observer
Barry Ackerman	DFO/Groundfish Management	X	X	X	PSARC member
Mark Saelens	ODFW/GMT	X	X		Observer
Vidar Wespedstad	PWCC		X	X	Observer
Patrick Higgins	Canadian Consulate Seattle		X		Observer
John Wallace	NMFS/NWFSC	X		X	Observer

Appendix 2. Summary of Stock Status (Helser et al. 2002)

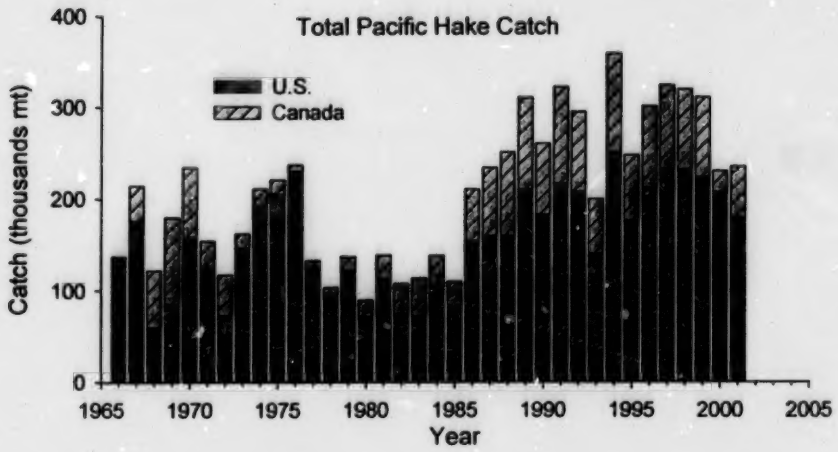
Summary of Stock Status

The coastal population of Pacific whiting (*Merluccius productus*, also called Pacific hake) was assessed using an age-structured assessment model. The U.S. and Canadian fisheries were treated as distinct fisheries in which selectivity changed over time. The primary indicator of stock abundance is the AFSC acoustic survey, and the SWFSC juvenile survey as an indicator of recruitment. Other data examined in the model were the AFSC triennial shelf trawl survey and the Department of Fisheries and Oceans acoustic survey. New data in this assessment included updated catch at age through 2001, recruitment indices from the SWFSC recruit survey, and results from the triennial acoustic and shelf trawl surveys conducted in summer of 2001.

Status of Stock: The whiting stock in 2001 was estimated to be at low biomass levels, however, projected stock biomass is expected to increase. Stock biomass increased to a historical high of 5.8 million t in 1987 due to exceptionally large 1980 and 1984 year classes, then declined as these year classes passed through the population and were replaced by more moderate year classes. Stock size stabilized briefly between 1995-1997, but has declined continuously over the past four years to its lowest point of 711 thousand t in 2001. The mature female biomass in 2001 is estimated to be 20% of an unfished stock. Mature female biomass, however, is projected to rise gradually over the next three years due to the relatively strong 1999 year-class as it enters the mature biomass of the stock. The percentage of unfished stock size depends, however, on the harvest policy chosen. For instance, under the F45% (40-10) harvest policy female spawning biomass increases to 31% (93% probability that females spawning biomass is greater than 25%B0) of an unfished stock in 2003. The exploitation rate was below 10% prior to 1993, but gradually increased to 31% by 2001. Biomass levels below 25%B0 and high exploitation rates indicate that the stock has been overfished in recent years primarily due to over-estimation of biomass in the 1998 assessment used to set optimum yield for 1999-2001. Furthermore, total U.S. and Canadian catches have exceeded the ABC by an average of 12% from 1993-1999 due to disagreement on the allocation between U.S. and Canadian fisheries.

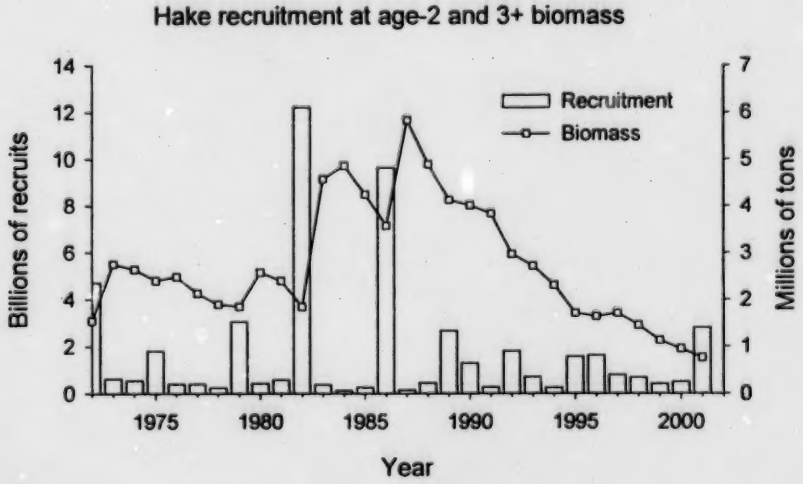
Pacific whiting (hake) catch and stock status table (catches in thousands of metric tons and biomass in millions of metric tons):

Year	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
U.S. landings	218	209	141	253	178	213	233	233	225	208	182
Canadian	105	86	59	106	40	88	91	87	87	22	53
Total	323	295	200	359	248	301	324	320	311	231	236
ABC	253	232	178	325	223	265	290	290	290	290	238
Age 3+ stock	3.8	3.0	2.7	2.3	1.7	1.7	1.7	1.5	1.1	1.0	0.7
Female mature	1.9	1.6	1.4	1.2	0.9	0.8	0.8	0.7	0.6	0.5	0.4
Exploitation rate	8.4%	10.0	7.4%	15.6	14.5	18.4	19.0	22.1	27.6	24.4	31.1



Data and Assessment: An age-structured assessment model was developed using AD model builder by Dorn et al. (1998), a modeling environment for developing and fitting multi-parameter non-linear models. Earlier assessments of whiting used the stock synthesis program. Comparison of models showed that nearly identical results could be obtained under the same statistical assumptions. The most recent assessment presented here for 2001 used the same model structure as in the 1998 assessment and examined different model assumptions regarding the strength of recruitment in 2001.

Major Uncertainties: The whiting assessment is highly dependent on acoustic survey estimates of abundance. Since 1993, the assessment has relied primarily on an absolute biomass estimate from the AFSC acoustic survey. The acoustic target strength of Pacific whiting, used to scale acoustic data to biomass, is based on a small number of *in situ* observations. The fit to the acoustic survey time series is relatively poor in the middle years (1983-1992) but improves early on and in more recent years. The AFSC shelf trawl survey biomass shows an increasing trend until 1995, conflicting with a decreasing trend in the acoustic survey since 1986. Both the acoustic and trawl surveys, however, show consistent declining trends since 1995.



Target Fishing Mortality Rates: Target fishing mortality rates used in projections were based on F40%, the fishing mortality rate corresponding to 40% of unfished spawning stock biomass-per-recuit, with the 40-10 policy implemented when biomass falls below 40% of unfished. A Bayesian decision analysis (Dorn et ai. 199) produced estimates of FMSY in the F40% to F45% range depending on the degree of risk-aversion. In addition to the F40% (40-10 option), F45% and F50% harvest policies were calculated under different assumed strengths of recruitment in 2001.

Projection table (Coastwide yield in thousands of tons, biomass in millions of tons, and percent unfished female spawning biomass) under different assumptions of recruitment strength in 2001 (low < 10%, medium 10%-90%, and high > 90%; percentiles based on 1,000,000 Markov chain Monte Carlo simulations) and different harvest policies:

Assumed 2001	Harvest Policy	Coastwide yield			3+ Biomass			Percent		unfished
Recruitment	(40-10)	2002	2003	2004	2002	2003	2004	2002	2003	2004
Low (2.12) bil.)	F40%	117	166	189	1.02	1.11	1.10	0.20	0.27	0.31
	F45%	96	141	166	1.02	1.13	1.15	0.20	0.28	0.32
	F50%	79	120	144	1.02	1.15	1.19	0.20	0.28	0.32
Med. (2.89) bil.)	F40%	162	217	228	1.26	1.33	1.26	0.24	0.32	0.34
	F45%	133	185	201	1.26	1.37	1.32	0.24	0.33	0.35
	F50%	109	158	176	1.26	1.39	1.37	0.24	0.33	0.36
High (3.87 bil.)	F40%	219	284	282	1.57	1.63	1.45	0.29	0.38	0.38
	F45%	180	242	250	1.57	1.67	1.53	0.29	0.39	0.39
	F50%	149	206	220	1.57	1.71	1.60	0.29	0.40	0.41

Other considerations: Unusual juvenile and adult distribution patterns have been seen in Pacific whiting population in recent years. Juvenile settlement spread northwards during 1994-99 due to El Niño ocean conditions. This was evident as numerous age-1 fish (1997 year class) seen in the 1998 acoustic survey off Queen Charlotte Islands as well as increased numbers of age-2 and age-3 whiting taken in the Canadian fishery in 1994 and 2000, respectively. Equally dramatic was the low occurrence of whiting off Canada in 2000 and 2001 resulting in less than full utilization of their TAC. This shift appears correlated with La Niña conditions in 1999-2000. It is unclear whether these changes will be a benefit or a detriment to stock productivity and stability. Despite the inconsistency in trends in biomass between the acoustic and trawl surveys, recent years (since 1995) have shown similar declines in whiting abundance. Possible strong recruitment in 2001 (1999 year class) along with substantial increases in mean weights at age due to favorable ocean conditions may prove to be positive factors in expected increases in yield and biomass in 2003-2004. However, projections of stock biomass and yields are highly dependent on the relative strength of recruitment in 2001.

Appendix 3. Decision table showing the repercussions of different assumptions for 2001 recruitment (1999 year-class) under different harvest strategies (Table 15 of Helser et al., 2002)

Values given show spawning biomass (as percent unfished) and exploitation rates as outcomes of choosing TACs for 2002-2004 associated with low (<10%), medium (10%-90%) or high levels (>90%) of 2001 recruitment (assumed state of nature) against low, medium and high true levels of recruitment (True state of nature).

		True state of nature 2001 Recruitment (billions)					
		Low (2.12)		Medium (2.89)		High (3.87)	
		Spawning biomass (as percent unfished)					
Management action	Assumed state of nature	2003	2004	2003	2004	2003	2004
F40% (40-10)	Low	27%	31%	33%	36%	41%	43%
F45% (40-10)	Low	28%	32%	34%	37%	41%	44%
F50% (40-10)	Low	28%	32%	34%	38%	42%	45%
F40% (40-10)	Medium	26%	28%	32%	34%	39%	40%
F45% (40-10)	Medium	27%	30%	33%	35%	40%	42%
F50% (40-10)	Medium	28%	31%	33%	36%	41%	43%
F40% (40-10)	High	25%	25%	31%	31%	38%	38%
F45% (40-10)	High	26%	27%	32%	33%	39%	39%
F50% (40-10)	High	27%	29%	32%	34%	40%	41%

		Outcome: Exploitation rate (2003-2004)					
Management action	Assumed state of nature	2003	2004	2003	2004	2003	2004
F40% (40-10)	Low	14%	14%	11%	12%	9%	10%
F45% (40-10)	Low	11%	12%	9%	10%	8%	9%
F50% (40-10)	Low	10%	10%	8%	9%	6%	7%
F40% (40-10)	Medium	19%	18%	15%	15%	12%	13%
F45% (40-10)	Medium	15%	15%	13%	13%	10%	11%
F50% (40-10)	Medium	13%	13%	11%	11%	9%	9%
F40% (40-10)	High	26%	25%	21%	21%	17%	17%
F45% (40-10)	High	21%	21%	17%	17%	14%	15%
F50% (40-10)	High	17%	17%	14%	15%	12%	12%